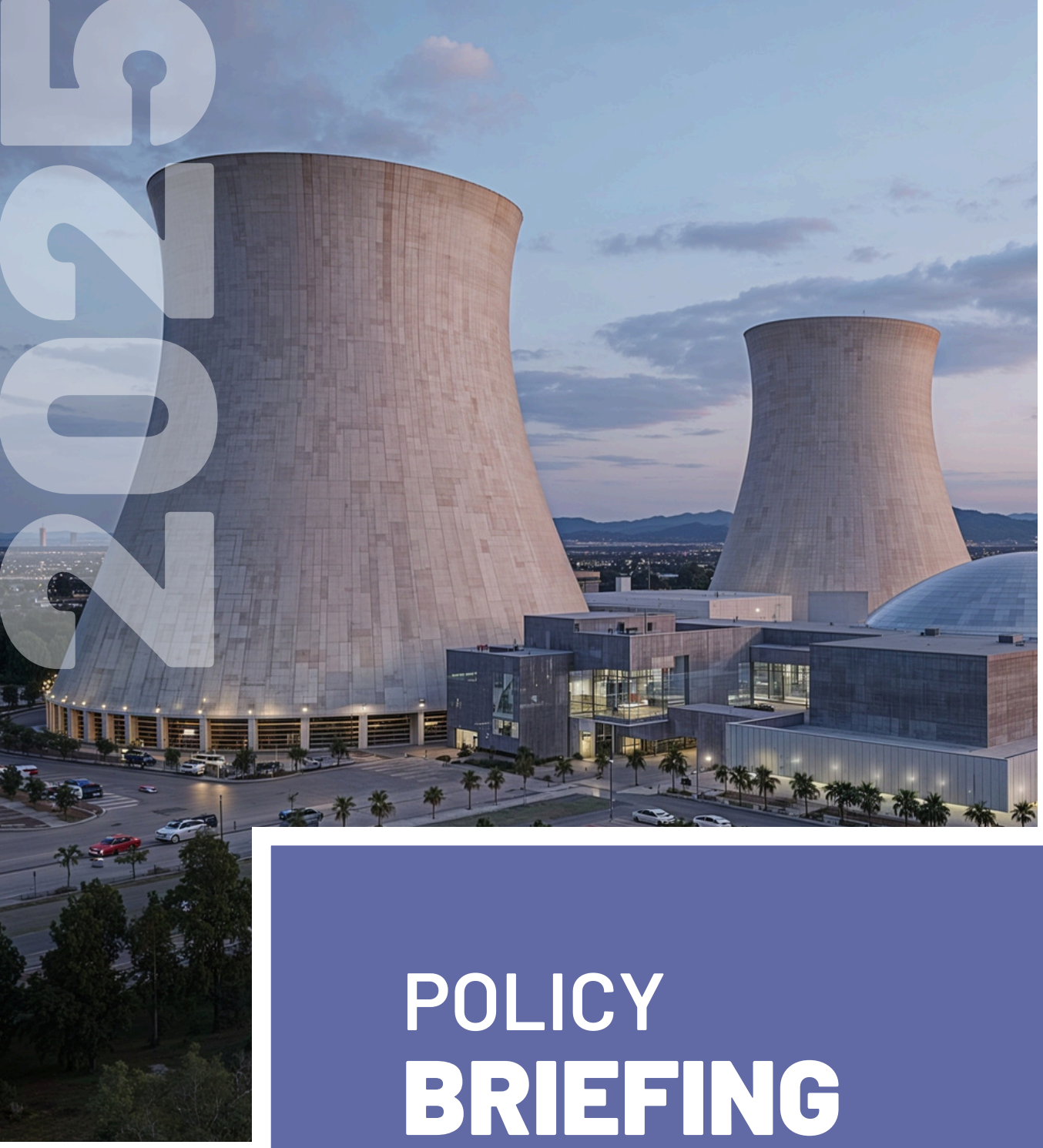
2025



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POLICY BRIEFING

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The future of nuclear energy in Spain

FUNDACIÓN RENOVABLES

General IDEAS

Throughout the report *"The Future of Nuclear Energy in Spain,"* published by **Fundación Renovables**, it is made clear that maintaining nuclear power plants in Spain **perpetuates a costly, inflexible, centralized, socially regressive**, and, by all accounts, **illegitimate energy model**. Far from being the solution to current problems, **nuclear power in Spain does not provide independence, resilience, or guarantees of supply, and it delays the transition to a safer, cleaner, more competitive, and fairer energy system.** The orderly and responsible closure of nuclear power plants is the most sensible option to **protect the public interest, guarantee the financial and environmental sustainability of the energy sector, and accelerate Spain's renewable energy leadership**.

The data on nuclear energy included in this document were obtained from information published by the nuclear sector itself. The sector's lack of transparency imposes research limitations that can sometimes lead to inaccurate financial, organizational, and operational data. These inaccuracies are not due to researcher bias, but rather reveal the opacity and secrecy of an industry that does not provide open information to the public and the government.

Nuclear Energy AT THE GLOBAL STAGE

The myth of nuclear revival

Globally, from 2010 to 2024, there is a marked divergence in the trends of installation of renewable sources (going from **1,227 GW** installed in 2010 to **4,448 GW** in 2024), that is, they multiply by **3.6, growing by 262%** compared to nuclear, whose growth during the same period is minimal (from **370.9 GW** installed in 2010 to **375.5 GW** in 2024, an increase of **1.2%**).

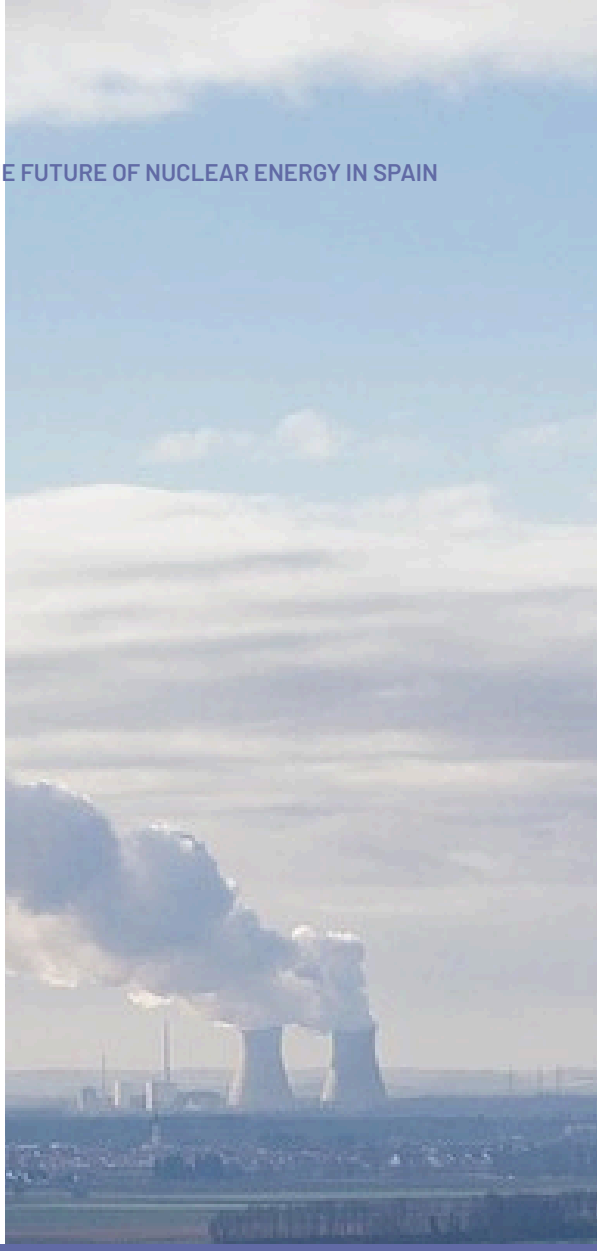
In total, from 2010 to 2024, **87.5 GW** of nuclear power has been built and **78.8 GW** has been closed, with **105** reactors ceasing operations and **90** coming online.

In 2010, nuclear power plants generated **2,629.8 TWh** of electricity worldwide, while in 2024 this figure fell to **2,617.5 TWh**, representing a **decrease of 0.5%**. However, renewable energy sources already generated more electricity than nuclear power in 2010, at **4,190 TWh** (primarily from hydroelectric power, accounting for over 90% of renewable generation), and by 2024 **9,839 TWh were generated, more than double what it was then.**

By technology, in the same period, solar photovoltaic generation has increased by **6,348.5%**, from **33 TWh** to the current **2,128 TWh**. Wind power increased from **342 TWh to 2,498 TWh, a rise of 630.4%.**

Asia accounts for 79% of the new nuclear capacity installed in the last decade, with China leading the way by commissioning 40 GW. However, in its strategic plan to 2060, China aims to have 180 GW of nuclear power installed (it currently has 55.3 GW) compared to more than 10,000 GW of combined solar and wind power.

During the 21st century, only thirteen nuclear power plants have been built or are under construction in 7 of the 38 OECD countries (Finland, France, South Korea, Japan, Slovakia, the United Kingdom and the United States).



Nuclear energy in Europe

The European Union (EU) shows a clear downward trend in nuclear capacity, falling from **120 GW in 2010 to 97 GW in 2024**, a **reduction of 19.5%**, mainly due to the closure of German reactors and the stagnation of the French nuclear fleet. Reactors that remain operational are generally old. Meanwhile, renewable capacity in the EU has grown from 254 GW in 2010 to 703 GW in 2024, almost tripling.

Nuclear power generation in the EU is declining from approximately **854 TWh in 2010** to around **648 TWh in 2024 (-24.1%)**. Meanwhile, renewables generated around **656 TWh in 2010** and reached **1,301 TWh in 2024 (+98%)**, significantly exceeding nuclear power (1.9 times more).

The state of private investment in Europe:

- Out of the total number of reactors in Europe, more than 78% (133) are owned by state-owned and state-controlled public companies, 13% (23) are exclusively privately owned (with the presence of consortia of private companies) and 8.2% (14) are owned by public-private consortia of private and state-owned companies.
- In the EU, 74% are publicly and state-owned, while both public-private and fully private ones account for 13%.
- In general, the delays and cost overruns of new reactors make nuclear power an unattractive option, in addition to the tax burden on nuclear operations, which is intended to partially finance waste management and other externalities generated by this technology. It is very common for the sector's financial losses to ultimately be socialized. A representative case is that of Areva and the impact of Fukushima on private sector confidence in nuclear power.

Current status of the Spanish nuclear sector

Spain has **seven nuclear reactors spread across five sites**, all built in the 1980s, prior to the privatization of the electricity sector. The average operating life of Spain's nuclear fleet is **40 years**, meaning that **most have exceeded their designed lifespan**.

The dismantling costs for the closed José Cabrera nuclear power plant are estimated at 217.8 million euros, and those for Garoña at 475 million.

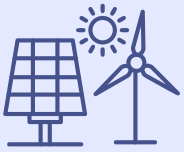
The over-dimensioning of the nuclear fleet and its subsequent moratorium, approved in 1984, has resulted in economic compensation of more than 5,700 million euros, according to the CNMC, collected through the electricity bill until 2015.

The cost of NUCLEAR ENERGY

Investment outlook in the energy sector

In 2023, global investment in renewables reached **$623,000 million**, solidifying its position as one of the main destinations for financial capital. Solar and wind energy account for the majority of these funds, presenting **exponential growth since 2010**.

In contrast, annual investment in nuclear energy has **remained relatively stable at around $30,000-35,000 million** over the past decade, **representing less than 2% of total energy transition investment** (almost 18 times less than investment in renewables) and mainly focused on maintenance and life extension activities for existing reactors.



623 MM$

GLOBAL INVESTMENT IN RENEWABLES IN 2023

30-35 MM$

AVERAGE ANNUAL INVESTMENT IN NUCLEAR

Overall costs and technological comparison

The levelized cost of energy (LCOE) of the new nuclear plant **($173/MWh)**, considerably higher than that of photovoltaics and wind power **(between $37 and $70/MWh)**, is indeed a significant factor. The argument that nuclear power guarantees the availability of electricity supply, especially at night, ceases to be valid when energy storage is a feasible and affordable option that also contributes to making the electrical system more flexible and resilient.

Security of electricity supply can be achieved by investing in storage and grid flexibility rather than new nuclear power.

The costs of European new nuclear

The experience of building nuclear reactors in Europe is a **story of cost overruns**: Olkiluoto-3 in Finland (from €3,000 million to €11,000 million), Flamanville-3 in France (from €3,300 million to €13,200 million), and Hinkley Point C in the United Kingdom (from €21,700 million to €53,000 million). All three cases show a common pattern of significant cost overruns and prolonged delays, which often ends up resulting in **the socialization of losses**, as they are assumed by the public rather than the companies that own the reactors.

The costs of nuclear in Spain

Currently, the full cost of producing nuclear electricity in Spain is largely unknown, reflecting the lack of transparency regarding the true costs of both the power plants and future investments. However, considering the known cost fractions corresponding to taxes and the Enresa fee, it can be stated that these are **generally insufficient to offset the negative externalities generated by nuclear activity**. These externalities primarily include the financing of **long-term radioactive waste management, with the current deficit exceeding €5,000 million.**

In fact, the Enresa fee should be multiplied by 6 to cover all the expenses estimated by the 7th Radioactive Waste Management Plan (PGRR) and the rest would have to be covered with public funds.

On the other hand, these future expenditure estimates increase with each new iteration of the PGRR. Specifically, the estimated cost of total waste and spent fuel management, including decommissioning costs, **increased by 4% from the 4th to the 5th PGRR, by 6% from the 5th to the 6th, and by 56% from the 6th to the 7th.**

At the same time, extending the lifespan of nuclear power plants only postpones the problem and can worsen the deficit, without guaranteeing coverage of the actual costs of closure and waste management. This **discredits the popular argument that the lack of competitiveness of nuclear power in Spain is due to an excessive and unfair tax burden.**

Although the cost of extending the life of a nuclear power plant is uncertain and depends on multiple factors, recent examples place the total cost between 25% and 50% of that of building a new plant. These extensions, beyond the reactor's original lifespan, also increase the risk of aging and failure due to fatigue, vessel corrosion (as seen in French reactors), and steel embrittlement. For example, the 10-year extension of the Belgian reactors Tihange 3 and Doel 4 through their nationalization for approximately €2,000 million is an option based on a "false nuclear economy" that should not be chosen when the alternative exists of replacing this nuclear power with hybrid renewable energy sources with storage.

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Electrical and nuclear generation IN SPAIN

Recent trends and seasonality in electricity generation

In 2024, monthly nuclear energy production in Spain ranged from 3,100 to 5,600 GWh. With minor monthly variations, nuclear power contributed a total of approximately 50,349 GWh annually, **representing around 20% of the electricity mix compared to 56% corresponding to renewables.**

When photovoltaic and wind power generation is combined, a complementary pattern emerges that smooths out individual fluctuations and covers seasonal baseload demand. This will be further enhanced by the nationwide deployment of energy storage for surplus injection and system manageability. For example, in July 2024, the combined solar and wind generation reached 10,047 GWh, while in November, when solar generation declines, wind power helped maintain a combined generation of 7,168 GWh. This synergy allows renewables to consistently outperform nuclear power every month of the year.

Analyzing the last ten years of electricity generation and demand (2015-2025), we can observe how the seasonal variability of renewables is smoothing out over time, as solar photovoltaics and wind power increase their share of the overall energy mix. Notably, from 2018 onwards, the growth of renewable generation accelerated, surpassing fossil fuel generation in several quarters. This increase coincides with the massive addition of new renewable capacity, especially solar photovoltaics.

The nuclear niche in the electricity mix

The urgency of the climate crisis, coupled with the rapid technological and industrial development of renewable energies and energy storage systems, **sets a pace that nuclear power cannot match in order to become either a viable alternative or a complementary energy source.** Currently, nuclear power is limited to maintaining a small presence in the electricity market, lacking the real capacity to meet present-day energy and environmental demands and challenges.

Spain possesses extraordinary renewable resources, along with the experience and conditions necessary for their successful deployment. This favorable situation **allows us to move away from nuclear power without resorting to fossil fuels as a replacement, and to have a renewable, flexible, efficient, and distributed electricity system.**

Spain's great native renewable potential allows to consolidate its **role as a generator of internal value and a net exporter of renewable energy to the rest of Europe.**

Additionally, nuclear power does not have the technical capacity to perform a dynamic control of grid voltage, which is required for grid stability, as renewables can do with *grid forming*.

The lifespan of the power plants and their closure **have been agreed** between the sector, ENRESA and the Government and any change must respect legal certainty and the responsibility of the owners in the management of waste and dismantling.

It is essential that **the owners assume the costs of safety, waste treatment and dismantling** exclusively, preventing them from falling on the General State Budget or on the electricity tariff of consumers.

Extending the life of the Almaraz power plant until 2030 would mean altering the plans that have guided investment in renewables in recent years, as well as abandoning the idea of a staggered and progressive closure that would soften the loss of nuclear generation, since it would mean closing the Almaraz I and II, Ascó I and Cofrentes reactors at the same time in 2030.

Effect of nuclear power on the price of electricity

In Spain, the average price of nuclear power generation exceeds **€65/MWh**, according to figures published by the nuclear sector itself, although their accuracy is not guaranteed due to the sector's lack of transparency. This figure is **significantly higher than that of wind and solar photovoltaic (PV)**, whose prices have fluctuated between **€24 and €43/MWh** in recent years and which already lead the market in terms of cost, pace, and volume of deployment. In fact, current base cases for financing are based on around **€30/MWh**. Since the marginal pricing system used for the electricity market assigns the price of electricity to the most expensive technology in the energy mix, the presence of nuclear and gas drives up the price of electricity in Spain.

Future scenarios for nuclear power generation

In any of the three nuclear closure scenarios by 2030 that we have developed for this report (current schedule, extension of Almaraz I and II, and extension of Almaraz I and II, Ascó I and Cofrentes), combined with the renewable deployment projected to achieve the National Integrated Energy and Climate Plan (PNIEC) objectives by 2030, **the total dominance of the energy mix is solar and wind**, with an annual generation of 150,253 GWh solar (photovoltaic and thermal) and 130,102 GWh wind indicated by the PNIEC by 2030. This growth in renewable generation must be accompanied by a **substantial increase in storage to 25,099 GWh**.

Based on these projections, there is a clear **need to increase the rate of installation of renewables and storage** from 2024 onwards in order to achieve the PNIEC targets by 2030, which is a complex task. However, it is worth mentioning that, according to REE (Red Eléctrica de España), there are already enough renewable energy and storage projects in Spain with access and connection permits to exceed the installed capacity requirements of the PNIEC 2030. Furthermore, funding has been confirmed for more than **3 GW of distributed storage** through the EHRA and ERDF funds, and the implementation of Operation Procedure 7.4 has been confirmed to aid this objective.

Furthermore, even without the renewable deployment ambition dictated by the PNIEC, simply maintaining the current rate of solar and wind installation would allow nuclear generation to be replaced by renewables completely and effectively.

Incompatibility of nuclear with the renewable model and the energy transition

In Spain, **nuclear power poses an obstacle to renewable development and the flexibility of the electricity system**.

Nuclear exhibits a notable **operational rigidity** since it requires functioning as **baseload power at full capacity**, which hinders and reduces the integration of indigenous renewables.

In situations of high renewable energy production, nuclear power and a lack of storage capacity lead to **grid congestion** or saturation, where **nuclear power remains the base of the energy mix and renewables are forced to be shut down**. This poses an economic obstacle to the continued installation of renewable energy capacity.

The closure of nuclear power plants is necessary for **market prices** to make renewable energy investments viable, since they compete under the same pricing model.

In Spain, the **capacity for renewable self-sufficiency** has already been demonstrated on various occasions, and the installation of storage and the PO 7.4 project is in progress, which will allow for further completion of renewable autonomy and system flexibility.

Even with several nuclear reactors shut down, the national electricity demand has been largely met with renewables at key times, demonstrating that **nuclear energy is not essential for security of supply in Spain.**

Droughts and their relationship to nuclear energy

The dependence of renewable energy generation on weather conditions is evident. However, **nuclear power is also affected by climate fluctuations and seasonality.** As a source of thermal energy, it requires constant cooling, which is also necessary for safety reasons to prevent the reactor core from overheating. This is achieved **using large flows of liquid water** from nearby bodies of water.

The forced reduction of French and Swiss nuclear power has been observed due to the effect of the heat wave experienced in Europe in June 2025 on the temperature of river water, which **prevents its use as a nuclear coolant without violating environmental regulations.**

These periods of extreme heat will become increasingly common.

Although it is true that the construction of cooling towers allows to mitigate the dependence on external water flows (with their extra cost), the European Commission estimates that **the increasing droughts will cause a reduction in nuclear generation of between 1% and 5%**, depending on the scenario considered, **with Spain being one of the most affected regions in Europe** along with Sweden and Slovakia.

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The promises and disruptions of NUCLEAR TECHNOLOGIES

Small-scale reactors (SMRs) have been considered the next step in nuclear fission technology. However, most models are **still in the research and development phase**, with only three examples of SMR reactors in commercial operation. Their cost, between **€100 and €118/MWh**, is three times higher than that of wind or solar power.

In the field of **nuclear fusion**, the reactor prototypes currently being developed are also in the **research phase**, still far from the commercial maturity needed to allow their deployment.

Besides posing major barriers to the hypothetical large-scale deployment of these technologies, the urgency of the climate crisis and the 2050 targets are **incompatible with a future commitment to SMRs and fusion** as a guarantee of clean energy supply.

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THE FUTURE OF NUCLEAR ENERGY IN SPAIN

2025

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